Field volatility of Dicamba BAPMA

Report:	MRID 51049004. Brayden, B.H., Rice, A.P., and Sisco, L.B. Off-target Movement Assessment of a Spray Solution Containing BAS 183 22 H and a Tank Mix Partner – Illinois. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by BASF Corporation, Research Triangle Park, North Carolina. Stone Study ID: 19-058-B. Eurofins Study ID: 89023. BASF Study ID: 884979. Agvise Study ID: 19-123 and 19-1459. Experiment initiation August 7, 2019 and completion September 4, 2019 (p. 6). Study and Report completion January 28, 2020.
Document No.:	MRID 51049004
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with US EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site observations, slope estimates, pesticide and crop history, soil taxonomy, and study weather data (p. 3). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification (Report Approval) statements were provided (pp. 2-4, and 7).
Classification:	This study is **acceptable**. Monitoring started after the conclusion of application. An independent laboratory method validation was not conducted. The addition of an approved buffering agent was included in the tank mix but was not included in the protocol reviewed by EPA. This adds uncertainty to the volatile flux rates, as the buffering agent may have reduced volatility of dicamba.
PC Code:	100094

Final EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: Chuck Peck Date: 2020.10.24 22:39:44 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist	Signature: Date: 2020.10.25 12:32:29 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Dan Hunt, M.S. Environmental Scientist	Signature: Dan Hunt Date: 4/28/20
	Richard Lester Environmental Scientist	Signature: Richard R Lester Date: 4/28/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba formulation BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt) when tank mixed with Roundup PowerMax®, Intact™ (polyethylene glycol, choline chloride, and guar gum), and an approved buffering agent was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in Shelby County, Illinois. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of application (8/7/19) ranged from 18.2-29.6°C (64.8-85.3°F), 20.1-39.6°C (68.2-103°F), and 54-98%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 14.0-31.7°C (57.2-89.1°F), 17.5-49.8°C (63.5-121°F), and 39-98%, respectively, 1 to 7 days after application.

Under field conditions at the test plot, based on calculations using the Indirect method, study authors estimated a peak volatile flux rate of 0.000492 $\mu g/m^2 \cdot s$, accounting for 0.016% of the applied dicamba observed 0.4 to 5.8 hours post-application. By the end of the study, study authors estimated that a total of 0.091% of dicamba volatilized and was lost from the field. The reviewer confirmed the peak flux rate and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.096%. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

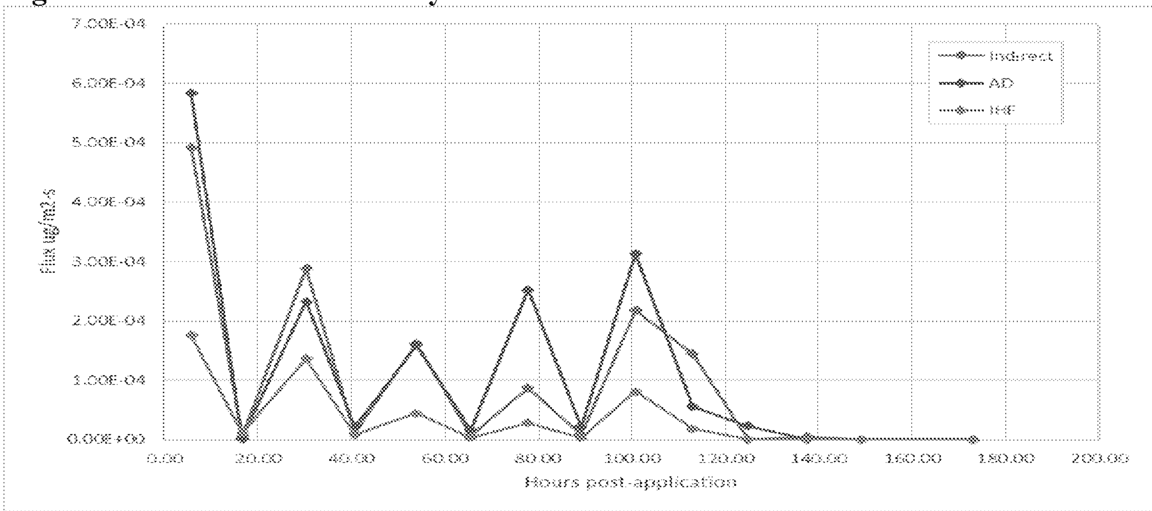
Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, study authors estimated a peak volatile flux rate of 0.000148 $\mu g/m^2 \cdot s$, accounting for 0.004% of the applied dicamba observed 0.7 to 5.3 hours post-application. By the end of the study, study authors estimated a total of 0.030% of dicamba volatilized and was lost from the field. The reviewer estimated a slightly higher peak flux rate (0.000168 $\mu g/m^2 \cdot s$) and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.032%. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, study authors estimated a peak volatile flux rate of 0.000728 $\mu g/m^2 \cdot s$ accounting for 0.022% of the applied dicamba observed 0.7 to 5.3 hours post-application. By the end of the study, a total of 0.097% of dicamba volatilized and was lost from the field. The reviewer estimated a slightly lower peak flux rate (0.000583 $\mu g/m^2 \cdot s$) and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.104%. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Spray drift measurements indicated that dicamba residues were not detected in the upwind samples during the hour after application and were detected at a maximum fraction of the applied deposition of 0.008692 in downwind samples. Deposition of dicamba above the no observed adverse effects concentration (NOAEC) was detected in all downwind transects in the one-hour

sampling period. Estimated distances from the edge of the field to reach NOAEC for soybean were 12.3 m (6.5 to 15.4 m for each transect) in the downwind direction using the reviewer-developed curves and ranged from 4.7 to 12.8 m in the downwind direction for the study author developed curves.

Figure 1 Volatile flux – Soybean Plot



Plant Effects Evaluation

The effect of **BAS 183 22 H (a.i. Dicamba BAPMA salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact^{TM}** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.050 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On days 14 and 28 after treatment, the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury (VSI).

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height (Table 1). All down wind (DW) transects showed significant distance-dependent response patterns for reductions in plant height.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. Percent of visible symptoms was a maximum of 45% in drift analysis transects at 28DAT. At day 28, the downwind (DW) drift transects showed an increase in symptomology up to 30-50%. Symptomology showed a distance-dependent response along the DW transects only.

Furthest distance to 5% Reduction in Plant Height = 36 meters (118.1 feet)
Furthest distance to 10% VSI 52 meters (171 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

The reviewer compared individual average plot heights to the 5% threshold based on control heights and visually selected the distances representing the point where plant height was not different from the controls. The study author did not statistically analyze plant height for any of the volatility transects. These estimated distances should be interpreted with caution.

The percent VSI was a maximum of 10% (RWB). There was no distance-dependent symptomology along any of the volatility transects.

Furthest distance to 5% Reduction in Plant Height <20 meters (<65.6 feet)
Furthest distance to 10% VSI < 3 meters (<9.8 feet)

Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

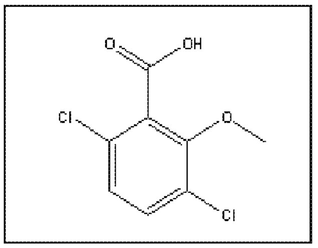
Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	5[b]	34[d]	<3[c]	<3[c]
DWB	32[b]	52[d]	<3[c]	<3[c]
DWC	36[b]	50[d]	<3[c]	<3[c]
LWA	<3[c]	<3[c]	<10[c]	<3[c]
LWB	<50[c]	<3[c]	<20[c]	<3[c]
UWA[e]	<20[c]	29[b]	<3[c]	<3[c]
UWB	<3[c]	<3[c]	<3[c]	<3[c]
RWA	<60[c]	<3[c]	<3[c]	<3[c]
RWB	<3[c]	<3[c]	<3[c]	<5[c]
N	125[a]	<3[c]	NA	NA
S	<3[c]	<3[c]	NA	NA
E	<20[c]	<3[c]	NA	NA

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
W	<3[c]	<3[c]	NA	NA

[a] distance estimated with linear regression
[b] distance estimated with logistic regression
[c] distance estimated visually
[d] distance estimated with polynomial regression
[e] transect impacted by runoff exposure
NA = Not applicable

I. Materials and Methods

A. Materials



1. Test Material

Product Name: BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt; Appendix B, pp. 101-102)
Formulation Type: SL
CAS #: 105-83-9
Lot Number: 7195N01DD
Storage stability: The expiration date of the test substance was July 18, 2020.

Product Name: Roundup PowerMax® (Glyphosate, (N-(phosphonomethyl) glycine potassium salt; Appendix B, p. 103)
Formulation type: Not reported
CAS Number: Not reported
Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 7, 2020.

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Not reported
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was August 7, 2022.

Product Name: Approved buffering agent (ABA)
Formulation type: Not reported
Lot Number: LH-171009-0001

Storage stability: The expiration date of the test substance was August 7, 2022.

2. Storage Conditions

The test substance was received on May 8 and July 24, 2019 and stored at SynTech Research, Inc., Stewardson, Illinois (Appendix B, p. 102). Roundup PowerMax® was received on May 9, 2019. Intact™ was received on May 9 and May 15, 2019. The ABA was received on May 15, 2019. The test substance was sprayed on the test plot on August 7, 2019 (Appendix B, p. 106). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, p. 34).

B. Study Design

1. Site Description

The test site was located in Shelby County, Illinois, *ca.* 1 mile east of Stewardson, Illinois (Appendix B, p. 104). A single soybean-cropped field, measuring *ca.* 900 ft x 900 ft (274 m × 274 m, 18.6 A) was treated with a mixture of BAS 183 22 H (containing dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt), Roundup PowerMax® (containing glyphosate potassium salt), Intact™ (polyethylene glycol, choline chloride, and guar gum), and an approved buffering agent (Appendix B, pp. 101-104). The crop on the plot was a dicamba-tolerant soybean crop (Variety: AG36X6, Lot: WN85BL2X) with a 430-ft buffer surrounding the plot planted in non-tolerant soybeans (Variety: PGL3590, Lot: SN8001). Soil characterization indicated the USDA textural class was silt loam (Appendix B, Table 2, p. 123). No dicamba applications occurred in the 3-year period prior to the study (Appendix B, p. 105). Crop history for the three years preceding the study indicated the field had been planted in soybeans and corn (Appendix B, p. 157). Terrain was flat with a slope between 0 and 2% (Appendix B, p. 104). The test plot was surrounded by agricultural land (Appendix B, Figures 2-4, pp. 139-141). The test plot and surrounding buffer zone were planted with soybean on June 13, 2019 and replanted on July 16, 2019 as a result of damage due to heavy rain (Appendix B, p. 104). The soybean seeds were planted at a density of 140,000 seeds/A on 30-inch row spacing for both plantings.

2. Application Details

Application rate(s): The target application rate was 0.5 lb a.e./A or 15 GPA (Appendix A, p. 34; Appendix B, p. 105). Four application monitoring samples consisting of four filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 109).

The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 115). The actual application rate was 103% of the target application rate or 15.4 GPA calculated by a Raven Applied Technology Viper 4+ field computer (Appendix B, Table 1, p. 122).

Irrigation and Water Seal(s): No irrigation or water seals were reported in the study. Precipitation of 0.06, 1.70, and 0.44 inches was reported on day 4, 5, and 6 of the study, respectively (Appendix B, Table 10, p. 132).

Tarp Applications: Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (volatility; Appendix A, p. 40).

Application Equipment: A RoGator 1074 ground sprayer equipped with a 100-ft boom was used for the spray application (Appendix B, p. 105). 60 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 20-inch spacing and the boom height was set at 20 inches above the crop canopy (17 cm). The sprayer had one spray tank with a volume of 1100 gallons.

Equipment Calibration Procedures: Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 105). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 29.8 GPM. The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 300 ft. Speed verification was repeated three times.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	8/7/2019 at 14:18	9.579	18.6	0.515	15.4

Data obtained from Appendix B, p. 106 and Appendix B, Table 1, p. 122 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, Table 1, p. 122).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period
Soybean	18.6	8/7/2019 between 14:18 – 14:34	8/7/2019 between 14:41 – 20:04	Not Applicable	Not Applicable

Data obtained from Appendix B, p. 106; and Appendix B, Table 4, p. 125 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 8/7/2019 between 15:00 – 19:33 (Appendix B, Table 4, p. 125).

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.1 (Appendix B, p. 108; Table 2, p. 123).

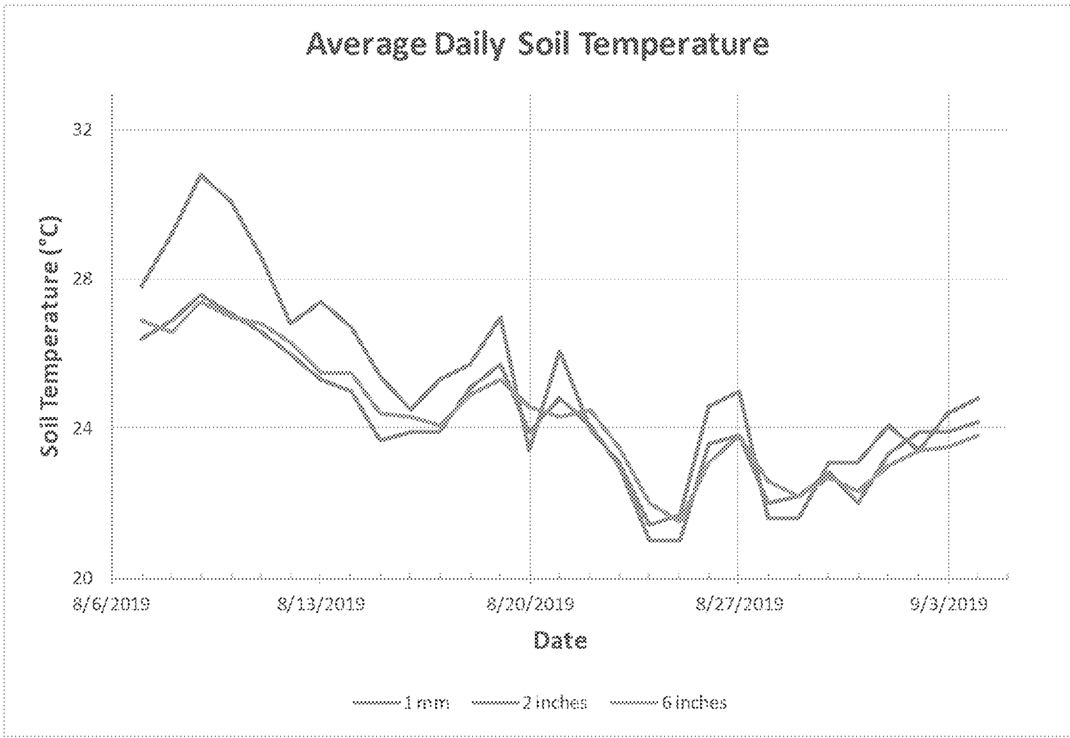
Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean	0-6	Silt loam	Not Reported	Not Reported	1.09	% Organic Carbon[1] = 1.05% % Sand = 12% % Silt = 70% % Clay = 18%

Data obtained from Appendix B, pp. 108, 117, and Appendix B, Table 2, p. 123 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 1.8%

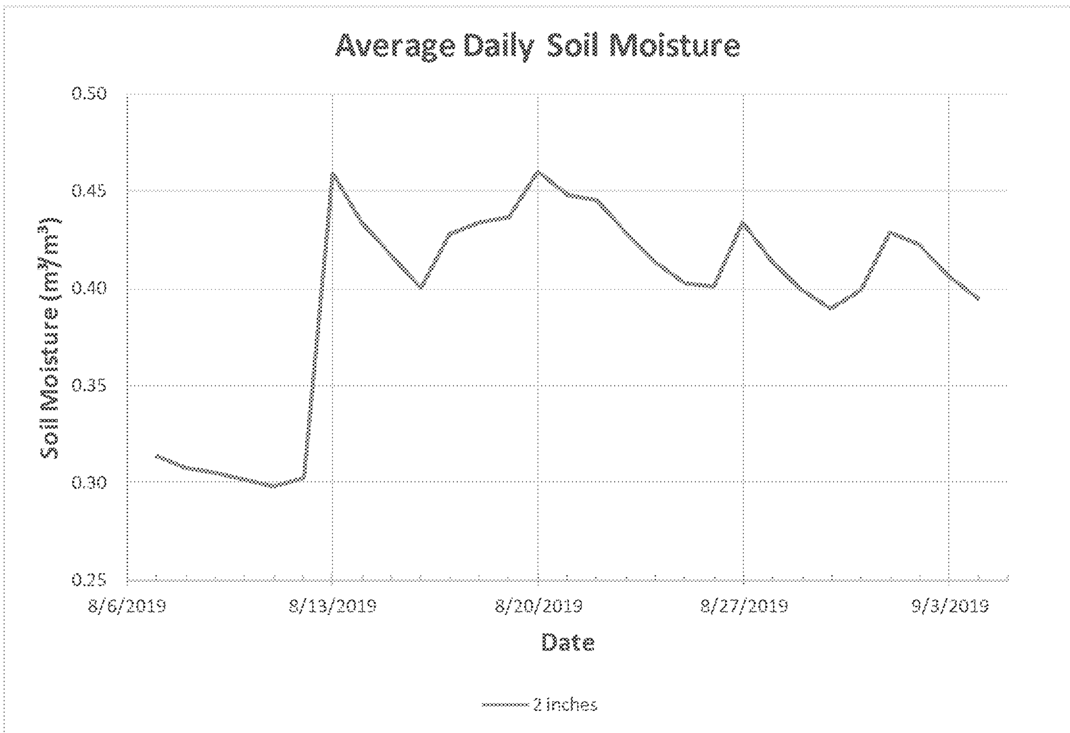
Figures 2 and **3** are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 11, pp. 134-135 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 11, pp. 134-135 of the study report.

4. Source Water

The source of the tank mix water was not provided in the study report. However, based on the location of where the tank mixing occurred (SynTech Research Inc in Stewardson, IL) and the similarities in the source water characterization to another study (MRID 51017502), the reviewer believes the source of the water was well water from the tank mixing facility. The pH of the tank mix water was 7.69 as measured at the field, 7.6 as measured at the analytical laboratory, an alkalinity of 57 mg $CaCO_3$/L, and a conductivity of 0.26 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 106).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, p. 107, and Figure 2, p. 139). The system included a Campbell CR6 data logger and a Campbell Scientific CELL 210 module to remotely monitor data. The station included sensors for monitoring windspeed and direction (one Gill 3D anemometer and two Gill 2D anemometers), air temperature, and relative humidity. All parameters were reported at heights of 1.7, 5, and 10 m.

A boom height anemometer collected wind speed and wind direction data during application at a height of 20 inches (51 cm) above the ground (Appendix B, p. 106). The anemometer was mistakenly placed 20 inches above the ground instead of 20 inches above the crop canopy at boom height. The anemometer was located *ca.* 3 m downwind of the sprayed area. Due to the mistaken placement height, data from the 0.55 m anemometer on the secondary flux meteorological station were used for wind direction and wind speed measurements at boom height.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 107, and Table 11, pp. 134-135). The station included wind speed and direction sensors (1.8 m), a rain gauge sensor (1.5 m), a temperature/relative humidity sensor (1.25 m), a pyranometer to measure solar irradiation (1.5 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to and during application and was then moved to the center of the plot, remaining there until after the final drift sample was collected on August 14, 2019 (Appendix A, p. 43; Appendix B, p. 107). The station included a Campbell CR6 data logger and a Campbell Scientific CELL 210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station also recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy

(Appendix B, p. 108). The secondary meteorological station was a backup flux meteorological station and was positioned northwest and outside of the sprayed area (Appendix B, p. 108). Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights[1] (m)	Averaging Period
Soybean Plot 10-Meter Main Met. Station	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute
		Wind speed/wind direction	1.7, 5, and 10	1 minute
Soybean Plot Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.51	Not Reported
Soybean Plot Long Duration Main Met. Station	Not Reported	Precipitation	1.5	1 minute
		Air temperature	1.25	1 minute
		Relative humidity	1.25	1 minute
		Soil temperature	1 mm, 2 inches, 6 inches	1 minute
		Soil moisture	2 inches depth	1 minute
		Solar radiation	1.5	1 minute
		Wind speed/wind direction	1.8	1 minute
Soybean Plot Primary Flux Met. Station	147.73	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute
Soybean Plot Secondary Flux Met. Station	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute

Data obtained from Appendix A, pp. 42-43; Appendix B, pp. 107-108; and Appendix D, Table 8, p. 566 of the study report.

[1] Monitoring heights are above soil surface for the 10-meter main meteorological station, boom height anemometer, and long duration main meteorological station. Heights are above crop canopy for the flux meteorological stations.

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop surface at the approximate center of the test plot (Appendix B, p. 110). Samples were collected for *ca.* 6 hours on August 6, 2019 from 11:13 to 17:12.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, pp. 110-111). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and 1.5 m above the crop canopy. Samples were collected at *ca.* 6, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sample from the 0 to 6-hour period represented less than 6 hours of sampling. Following the 0 to 6-hour interval, sampling was completed on a sunrise-sunset schedule, with consistent morning and evening sampling times.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 111). Samples were collected at *ca.* 6, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects. All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 120 m in the downwind transects and one leftwind transect. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 5 minutes after spray application was completed. Deposition samples were then collected at intervals of 1, 24, 72, 96, 120, 144, and 168 hours post-application (Appendix B, pp. 111-112).

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba-tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the tolerant soybean field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 120 meters (Appendix G, pp. 731-732; Figure 2, p. 758). Height effects and visual symptomology was recorded at 0, 14, and 28 days after spray application of the tank mix. Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, four upwind control areas were identified and evaluated for plant height.

Plant effects from volatility were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 731-732; Figure 3, p. 759). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment.

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, p. 108). PUF sorbent tubes and filter papers were placed in pre-labeled conical tubes. Pre-application, post-application, field-exposed spikes, and transit stability PUF samples were stored in an approximately -20°C freezer prior to shipment and were shipped in coolers containing dry ice to the analytical test site. Downwind, left wind, and right wind filter paper samples were stored in a freezer at *ca.* -20°C freezer prior to shipment and were shipped in coolers containing dry ice to the analytical test site. Upwind filter paper samples and application monitoring samples were stored in separate coolers packed with dry ice and shipped to the analytical lab. Tank mix samples were stored and shipped under ambient conditions. All samples, except for the soil and source water samples, were shipped via freezer truck to the analytical test site, Eurofins, in Columbia, Missouri. The soil and source water samples were shipped on wet ice to AGVISE Laboratories, Northwood, ND via FedEx (Appendix B, pp. 110-111).

All field collected PUF and filter paper samples were extracted within 21 and 19 days, respectively, after collection (Appendix C, p. 256-257). All field exposed QC and transit stability samples were extracted within 19 days after fortification. All PUF and filter paper samples were analyzed within 1 and 5 days of extraction. All PUF and filter paper samples were analyzed within 22 and 24 days of sampling, respectively (Appendix C, pp. 430-449). Stability was demonstrated in the study by the recovery of dicamba in fortified field QC and transit stability samples run concurrently with the field samples.

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipe (Appendix B, p. 110). SKC AirChek 52 air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 3.000 ± 0.050 L/min.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 256, 315-342). The sample was fortified with internal standard, grinding balls were added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.8 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean glass-lined polypropylene plate (2 mL) positioned below the filter plate (Appendix C, pp. 323-324). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 25% methanol in water. The sample was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode.

  The filter paper samples were extracted using methanol containing stable-labelled internal standard. The sample was fortified with internal standard, grinding balls were added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate. The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 343-362).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 335). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation is provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF (Appendix C, p. 334). For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.065 ng/PUF. During the study, the LOQ was 1.0 ng/PUF (p. 15).

  Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix C, pp. 357). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation is provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 µg/filter paper (Appendix C, p. 343). During the study, the LOQ was 0.005 µg/filter paper (p. 15).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 321). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 327 and 380).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix C, p. 348). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted quadratic curve (1/x; Appendix C, pp. 353 and 405).

11. Quality Control for Air Sampling

Lab Recovery: 16 of 24 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 383-384). All laboratory spike recoveries are within the range of 81-119%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (12 samples) and 60 ng/PUF (12 samples). Average recoveries were 99% and 102% at 1 ng/PUF and 60 ng/PUF, respectively.

Field blanks: Two pre-application samples were collected from the center of the test plot from 11:13 to 17:12 on August 6, 2019, one day before application (Appendix B, p. 110). Pre-application samples were <LOD and 0.341 ng/PUF (<LOQ), respectively (Appendix B, p. 117; Appendix C, Table 6, p. 267).

Control samples from the field spike analysis did not contain detectable levels of dicamba (Appendix C, Table 9, p. 275).

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Most field spike recoveries are within the acceptable range with overall recoveries of 77% to 102% at 3 ng/PUF, 81% to 101% at 10 ng/PUF, and 89% to 101% at 30 ng/PUF (Appendix B, p. 118; Appendix C, Table 8, p. 274).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, p. 114). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 96% to 101% (Appendix C, Table 9, p. 275).

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 96% to 110% (Appendix C, pp. 383-384). The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 9.4 ng/PUF (Appendix C, pp. 387-394) which is *ca.* 16% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 48 of 60 laboratory spike recoveries are within the acceptable range of 90-110%. All laboratory spike recoveries are within the range of 83-125%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (27 samples), 5 µg/filter (27 samples), and 50 µg/filter (6 samples). Average recoveries were 103%, 104%, and 100% at 0.005 µg/filter, 5 µg/filter, and 50 µg/filter, respectively. Control samples from the field spike analysis did not contain detectable levels of dicamba (Appendix C, p. 401-404).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 µg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 300). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 95% to 101%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area (Appendix B, p. 109). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target was 100% (Appendix B, p. 117; Appendix B, Table 12, p. 136; and Appendix C, Table 2, p. 263).

Spray application rates were automatically maintained by the sprayer using a variable rate controller (Appendix B, p. 115). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. The actual application rate was 103% of the target rate calculated by a Raven Applied Technology Viper 4+ field computer (Appendix B, Table 1, p. 122).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, p. 109). The average recovery relative to the target was 97% before application and 97% after application (Appendix C, Table 4, p. 265).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. U.S. EPA's AERMOD model (version 18081) was used to estimate deposition, while the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) was used to estimate air concentrations (Appendix E, p. 596). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 596). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM2 and the average flux rate and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different, particularly where weighted averaging occurred. However, they did not impact the overall modeling conclusions.

Wet and dry deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, p. 598). For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, maximum 24-hour average total (dry+wet) deposition ranged from 2.03 to 2.31 μg/m^2 (Appendix E, Table 7, pp. 611-612). 90th percentile 24-hour average total deposition ranged from 0.9831 to 1.2863 μg/m^2.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 597-599). Modeled 95th percentile air concentrations for an averaging period of 24 hours ranged from 3.5 to 5.8 ng/m^3 at 5 m from the edge of the treated field and 2.5 to 4.2 ng/m^3 at 50 m from the edge of the field (Appendix E, Table 6, p. 610).

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeled 95th percentile 24-hour air concentrations were slightly higher (4.7-11 ng/m3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 g/m$^{2}\cdot$s to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, the spatial relationship was removed by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, the ratio of the sum of the measured concentrations to the sum of the modeled concentrations was multiplied by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the “flux-gradient” method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1 $$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman’s constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2 $$Flux = \frac{-(0.42)^2(c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3 $$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + (u_{ztop} - u_{zbottom})^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = (1 + 16R_i)^{0.33}$ and $\phi_p = 0.885(1 + 34R_i)^{0.4}$

if R_i <0 (for Convective/Unstable IBL)
$\phi_m = (1-16R_i)^{-0.33}$ and $\phi_p = 0.885(1-22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was not satisfied at for any of the sampling periods. Average fetch distances ranged from 148 to 166 m, while the minimum fetch distance was 167 m (the highest height of the samplers was 1.67 m). As a result, there is some uncertainty in whether the plume was completely captured and in the resulting flux rates. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x}\int_{Z_0}^{Z_P} \bar{c}\bar{u}\,dz$$

where P is the volatile flux in units of µg/m^2·s, $\bar{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\bar{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 3 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P}(A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1-D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface roughness length was below the maximum surface roughness requirement of 0.1 meters for all monitoring periods.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 5.50 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (μg/m²·s)	Notes	Registrant (μg/m²·s)	Notes
1	8/7/19 14:41 – 20:04	5:23	0.000492	Regression	0.000492	A
2	8/7/19-8/8/19 19:23 – 7:00	11:37	0.000006	Regression	0.000006	A
3	8/8/19 6:08 – 20:37	14:29	0.000288	Regression	0.000288	A
4	8/8/19-8/9/19 19:33 – 7:02	11:29	0.000011	Regression	0.000011	A
5	8/9/19 6:42 – 20:10	13:28	0.000162	Regression	0.000162	A
6	8/9/19-8/10/19 19:19 – 7:45	12:26	0.000007	Regression	0.000007	A
7	8/10/19 7:13 – 20:05	12:52	0.000087	Regression	0.000087	A
8	8/10/19-8/11/19 19:14 – 7:28	12:14	0.000009	Regression	0.000009	A
9	8/11/19 7:09 – 19:10	12:01	0.000217	Regression	0.000217	A
10	8/11/19-8/12/19 18:34 – 7:24	12:50	0.000144	Regression	0.000144	A
11	8/12/19 7:10 – 19:12	12:02	0.000000	C	0.000000	B
12	8/12/19-8/13/19 18:40 – 7:56	13:16	0.000005	Ratio of averages	0.000005	B
13	8/13/19 7:35 – 19:34	11:59	0.000000	C	0.000000	B
14	8/13/19-8/14/19 18:59 – 7:17	12:18	0.000000	C	0.000000	B

Data obtained from Appendix B, Table 4, pp. 125-126 and Appendix D, Table 6, p. 564 of the study report.
Notes
A The spatial regression method was used to calculate the flux estimate for the sampling period.
B The ratio method was used to calculate the flux estimate for the sampling period.
C All measured values were below the limits of detection.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	Notes
1	8/7/19 15:00 – 19:33	4:33	0.000168 0.000583	0.000148 0.000728	IHF AD	
2	8/7/19-8/8/19 19:45 – 6:14	10:29	0.000012 0.000002	0.000011 0.000002	IHF AD	
3	8/8/19 6:19 – 19:38	13:19	0.000154 0.000232	0.000120 0.000230	IHF AD	
4	8/8/19-8/9/19 19:41 – 6:53	11:12	0.000008 0.000022	0.000008 0.000018	IHF AD	
5	8/9/19 6:55 – 19:24	12:29	0.000043 0.000158	0.000041 0.000147	IHF AD	
6	8/9/19-8/10/19 19:28 – 7:23	11:55	0.000004 0.000016	0.000003 0.000015	IHF AD	
7	8/10/19 7:27 – 20:29	13:02	0.000029 0.000252	0.000027 0.000191	IHF AD	
8	8/10/19-8/11/19 20:32 – 7:12	10:40	0.000004 0.000022	0.000004 0.000021	IHF AD	
9	8/11/19 7:13 – 18:42	11:29	0.000080 0.000312	0.000081 0.000252	IHF AD	
10	8/11/19-8/12/19 18:46 – 7:14	12:28	0.000018 0.000056	0.000019 0.000048	IHF AD	
11	8/12/19 7:16 – 18:47	11:31	0.000001 0.000023	0.000001 0.000019	IHF AD	
12	8/12/19-8/13/19 18:54 – 7:42	12:48	0.000000 0.000000	0.000000 0.000000	IHF AD	
13	8/13/19 7:50 – 19:07	11:17	0.000000 0.000000	0.000000 0.000000	IHF AD	
14	8/13/19-8/14/19 19:12 – 7:15	12:03	0.000000 0.000000	0.000000 0.000000	IHF AD	

Data obtained from Appendix B, Table 4, p. 125; Appendix D, Table 8, p. 566; and Appendix D, Table 10, p. 568 of the study report.
*Methods legend: ID = Indirect Method, AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.

The maximum flux rate calculated by the Indirect, Integrated Horizontal Flux and Aerodynamic methods occurred during the first sampling period after application. Maximum flux rates were 0.000492 $\mu g/m^2 \cdot s$, 0.000148 $\mu g/m^2 \cdot s$, and 0.000728 $\mu g/m^2 \cdot s$ for the Indirect, Integrated Horizontal Flux, and Aerodynamic methods, respectively (Appendix D, pp. 545-547).

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.753 for period 2 to 1.000 for period 10 (Appendix D, Table 6, p. 564). Spatial regression was used to estimate flux during all periods except periods 11-14, which used the ratio method.

R-squared values in log-linear vertical profiles of wind speed were generally high with all r-squared ≥0.961 (Appendix D, Table 8, p. 566 and Appendix D, Table 10, p. 568). R-squared values in log-linear vertical profiles of concentration were low for period 11 (0.512).

R-squared values in log-linear vertical profiles of temperature were less than 0.7 (0.004 – 0.65) for all but Period 7 (0.79). The reviewer confirmed this trend, but it is unclear if the poor regressions were the result of incorrect assignment of sampling values with height. An analysis of the temperature with height using the secondary flux meteorological station indicated a good fit for temperature with height, with the r-squared values ranging from 0.03 to 1.00, with 5 periods below an r-squared of 0.7 (Periods 2, 4, 6, 8, and 10), all of which were night time sampling periods. As such, the reviewer used the data from the secondary flux meteorological station.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.008692 at 3 m from the downwind edge of the field within the first hour after application (Appendix F, Table 2, pp. 646-648). Dicamba residues were not detected above the limit of quantitation in any of the upwind or right wind samples within the first hour after application. **Figure 4** depicts the deposition fractions and the reviewer-predicted spray drift curves for the downwind transects within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

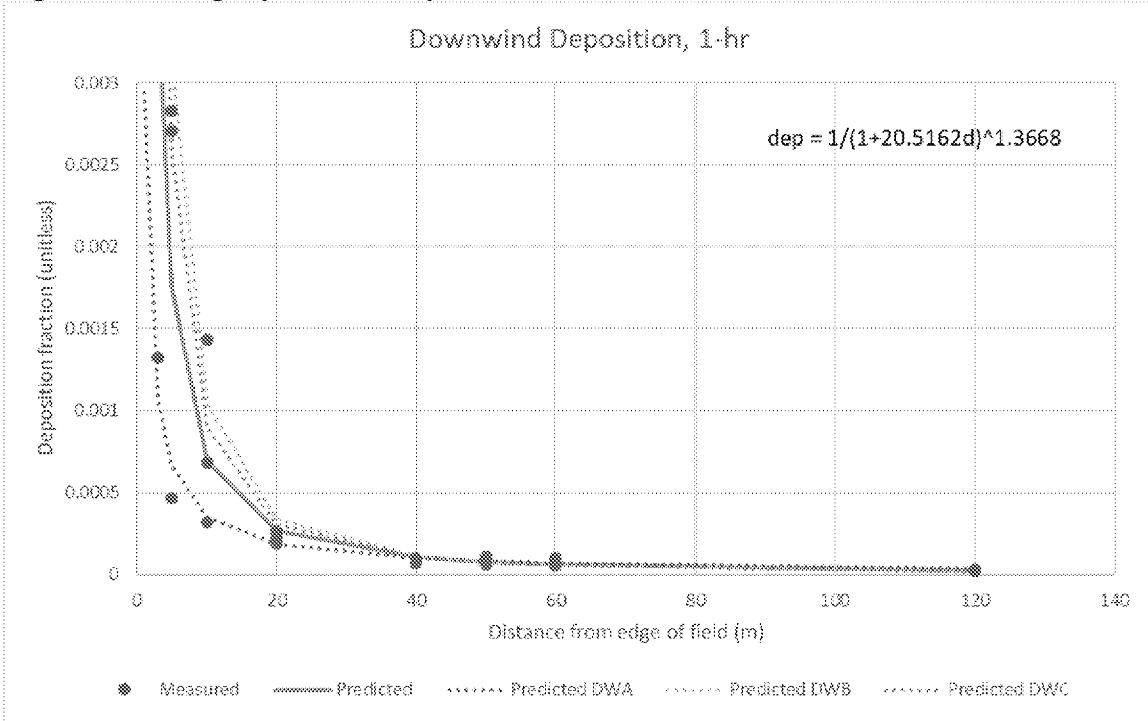
$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, p. 640). For the one-hour sampling period, the best fit models were the biexponential (downwind transect A), power with coefficient model (downwind transect B), and power with coefficient and intercept (downwind transect C; Appendix F, Table 3, p. 668) The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) were 12.3 m (6.5 to 15.4 m for each transect) in the downwind direction using the reviewer-developed curves and ranged from 4.7 to 12.8 m in the downwind direction for the study author developed curves (Appendix F, pp. 642).

Figure 4 Spray Drift Analysis for Downwind Transects– 1 Hour



D. Plant Effects Measurements

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height along the north (N) and downwind (DW) transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8 & 10). The best fit regression (as indicated by the R^2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Table 6b provides the estimated distances to 5% reduction in plant height for each transect. The north transect did not show a distance-response pattern consistent with decreasing exposure from the edge of the exposure area. Additionally there were low VSI reported for that transect, so reduced plant height relative to the controls may be reflective of poorer growing conditions along that transect. The furthest distances were estimated for the DW transects extending out to 36 meters for DWC.

Poor plant growth was reported in transect UWA, preventing plant measurements to be taken for the 3 and 5 m plots. These conditions were not identified at the pre-exposure sampling period (-2DAT). However, this is considered of minimal impact on the conclusions for the transect or study.

A major uncertainty in the implementation of this study was that the measurements of plant height were not consistently taken from the same individual plants over the course of the successive sampling events. No discussion was provided to explain how the plants were selected such to prevent selection of the healthiest looking plants from a plot. This uncertainty may contribute to underestimation of effects and therefore underestimation of off-field distance estimates.

Visual Signs of Injury (VSI)

Visible symptomology was reported, but the specific phytotoxic symptoms were not detailed for the transects. The DW, UWA, and RWA transects showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. For these transects, linear, logistic and polynomial regression methods in Excel to estimate the distance to the point where 20% VSI would be predicted (Figures 7, 9 & 11). The furthest distances to 20% VSI were consistent with the transects that showed significant effects on plant height and ranged from 11 meters to 25 meters (36 to 82 feet; Table 6b).

Volatility Exposure (covered) Transects

Measures indicate that impacts to plant height were significantly less than observed along the uncovered transects. Effects were observed along LW transects with a maximum 20% effect distance estimated at 10 meters (32 feet; Table 6b). Only transect RWB reported 20% VSI, all other transects showed either no VSI or much less than 20%. Distances were visually estimated as less than 5 meters for VSI.

Table 6b. Distance to 5% height and 20% VSI for 28DAT measures.

Exposure Pathway	Spray Drift + Volatility		Volatility (Covered Plots)	
Transect	Distance to 5% Height (meters)	Distance to 20% VSI (meters)	Distance to 5% Height (meters)	Distance to 20% VSI (meters)
DWA	5[b]	11[b]	<3[c]	<3[c]
DWB	32[b]	25[b]	<3[c]	<3[c]
DWC	**36[b]**	**24[b]**	<3[c]	<3[c]
LWA	<3[c]	<3[c]	<10[c]	<3[c]
LWB	<50[c,d]	<3[c]	<20[c]	<3[c]
UWA	<20[c]	18[b]	<3[c]	<3[c]
UWB	<3[c]	<3[c]	<3[c]	<3[c]
RWA	<60[c,d]	<3[c]	<3[c]	<3[c]
RWB	<3[c]	<3[c]	<3[c]	<5[c]
N	>120[a,d]	<3[c]	NA	NA
S	<3[c]	<3[c]	NA	NA
E	<20[c]	<3[c]	NA	NA
W	<3[c]	<3[c]	NA	NA

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for field corner transects (N,S,E,W).

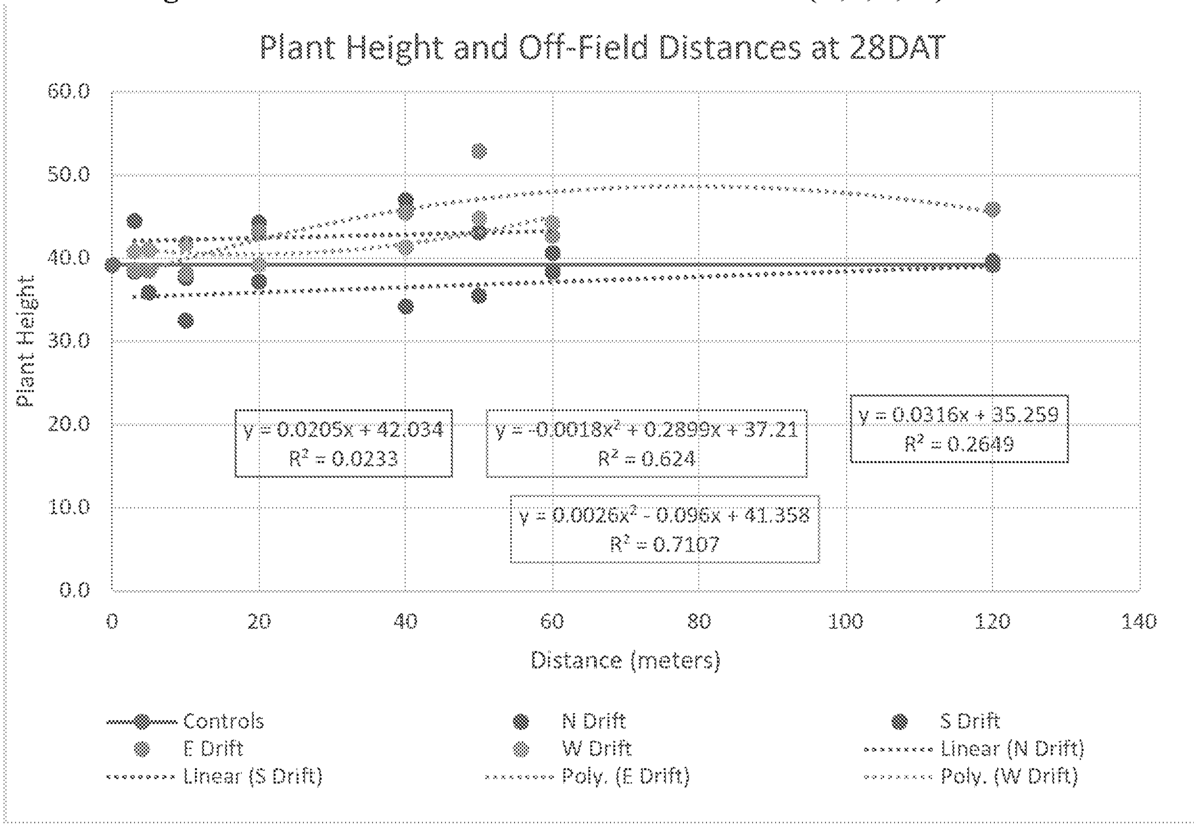


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for the treated area for field corner transects (N,S,E,W).

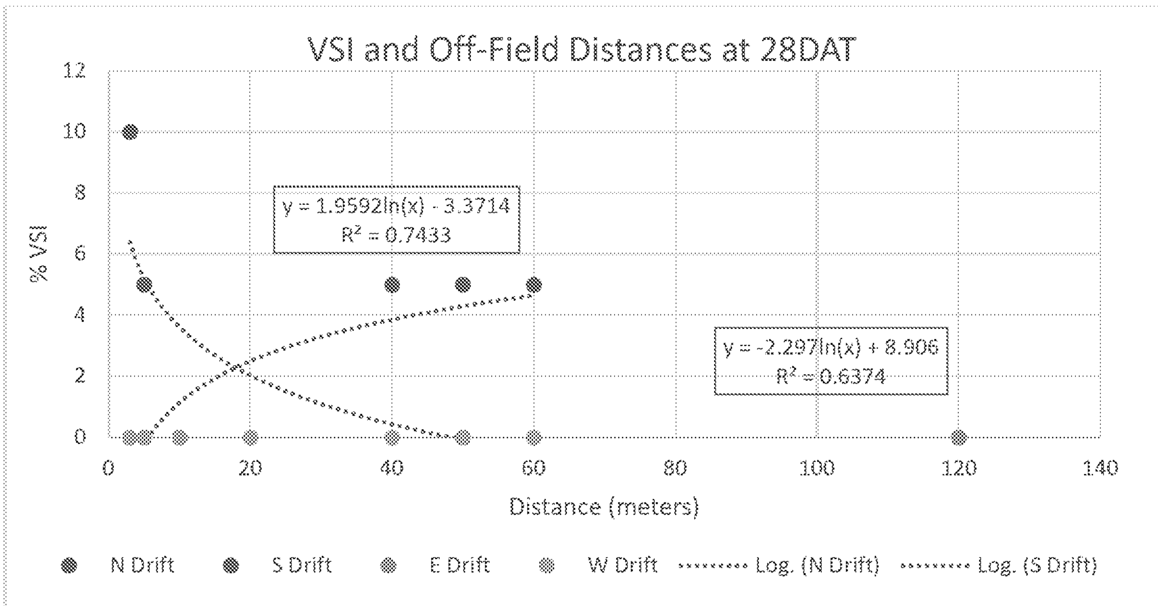


Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Right Wind" transects.

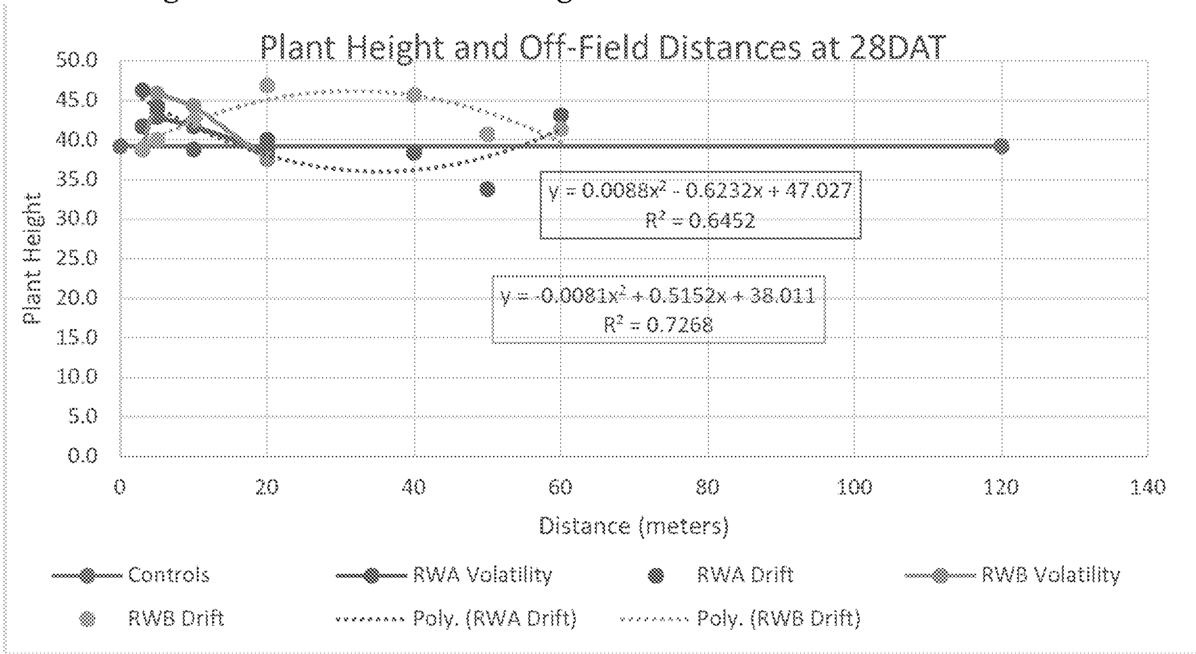


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Right wind Transects".

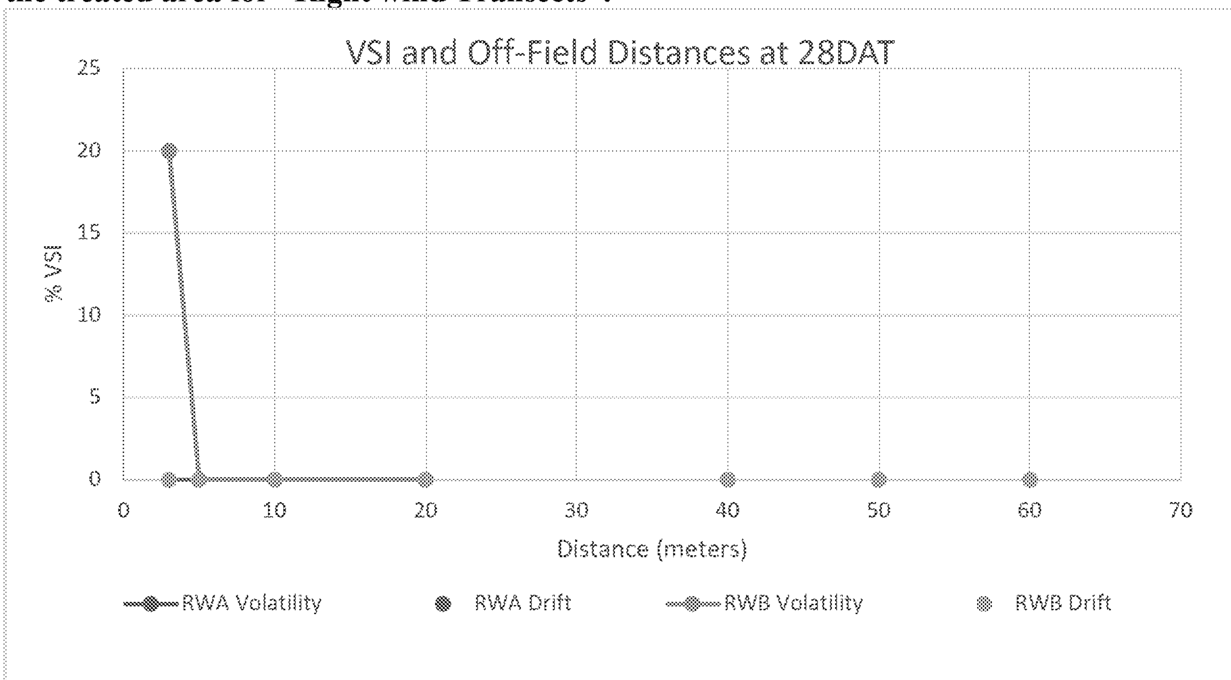


Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" transects.

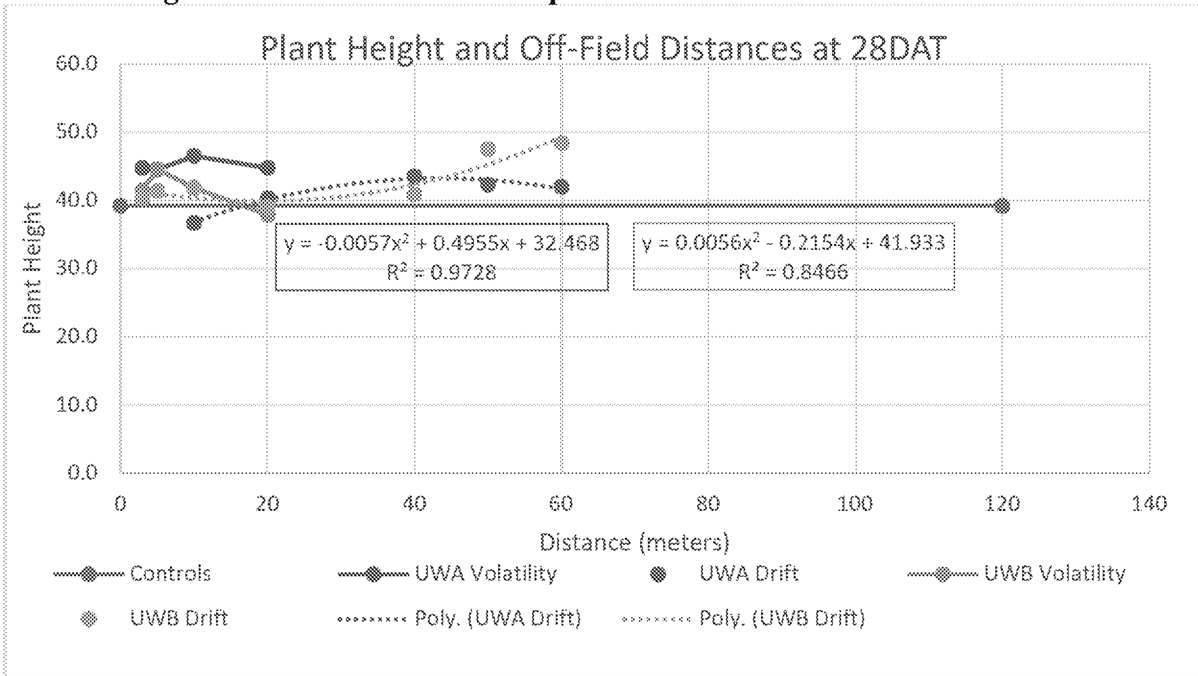


Figure 11: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up wind Transects".

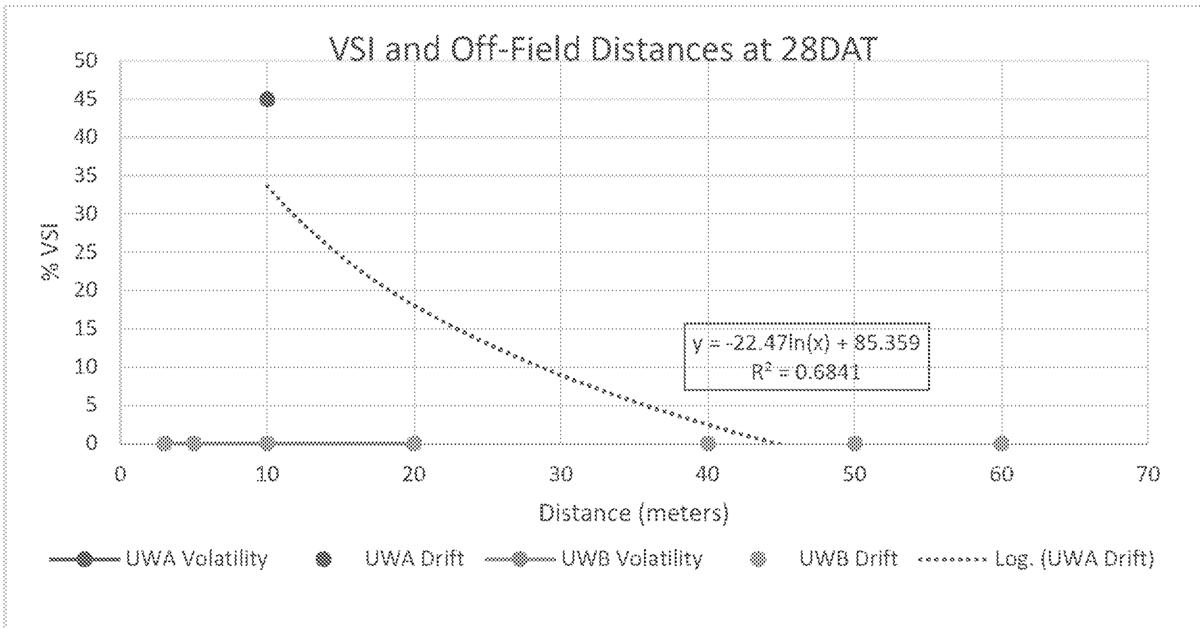


Figure 12: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" transects.

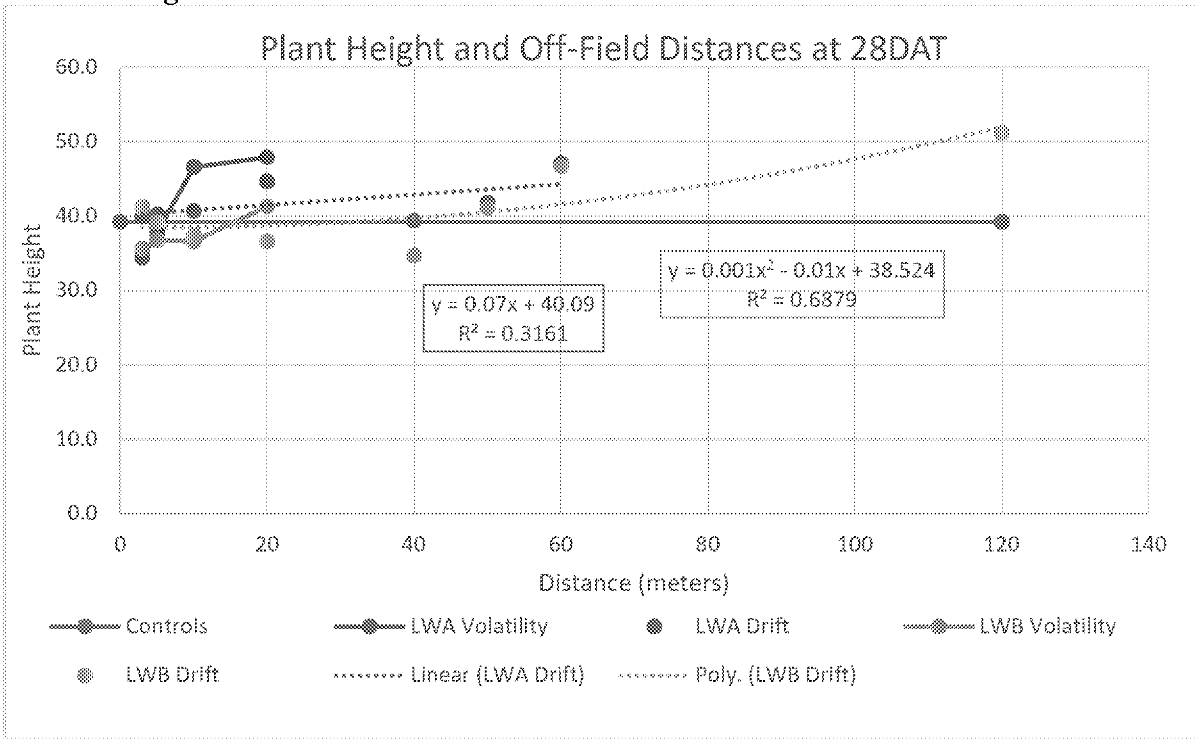


Figure 13: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left wind Transects".

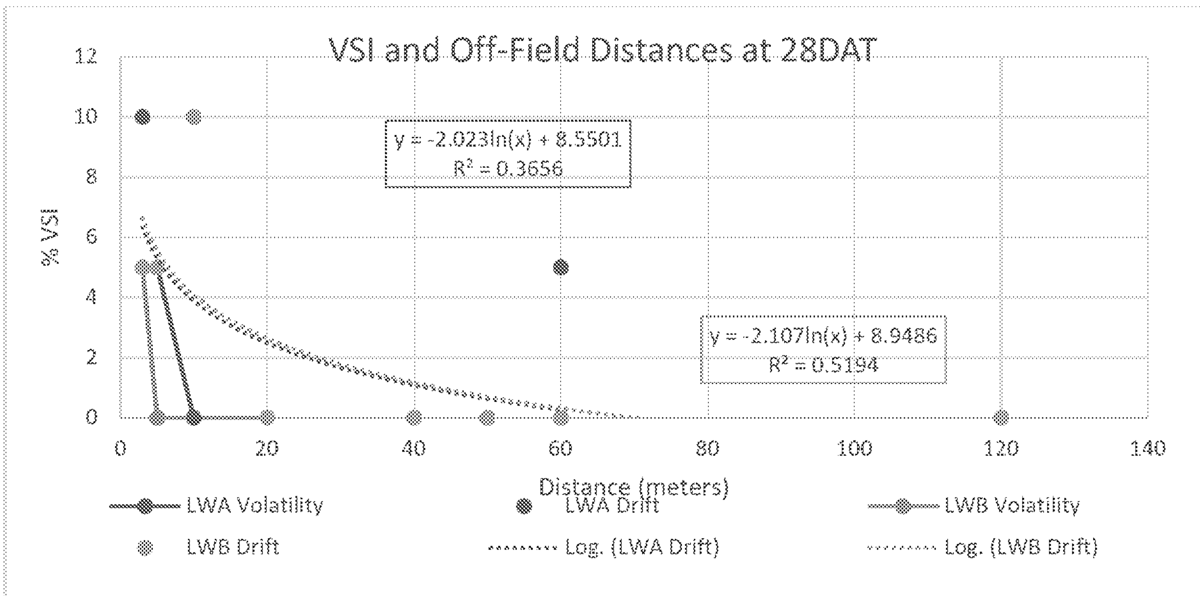


Figure 14: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Down Wind" transects.

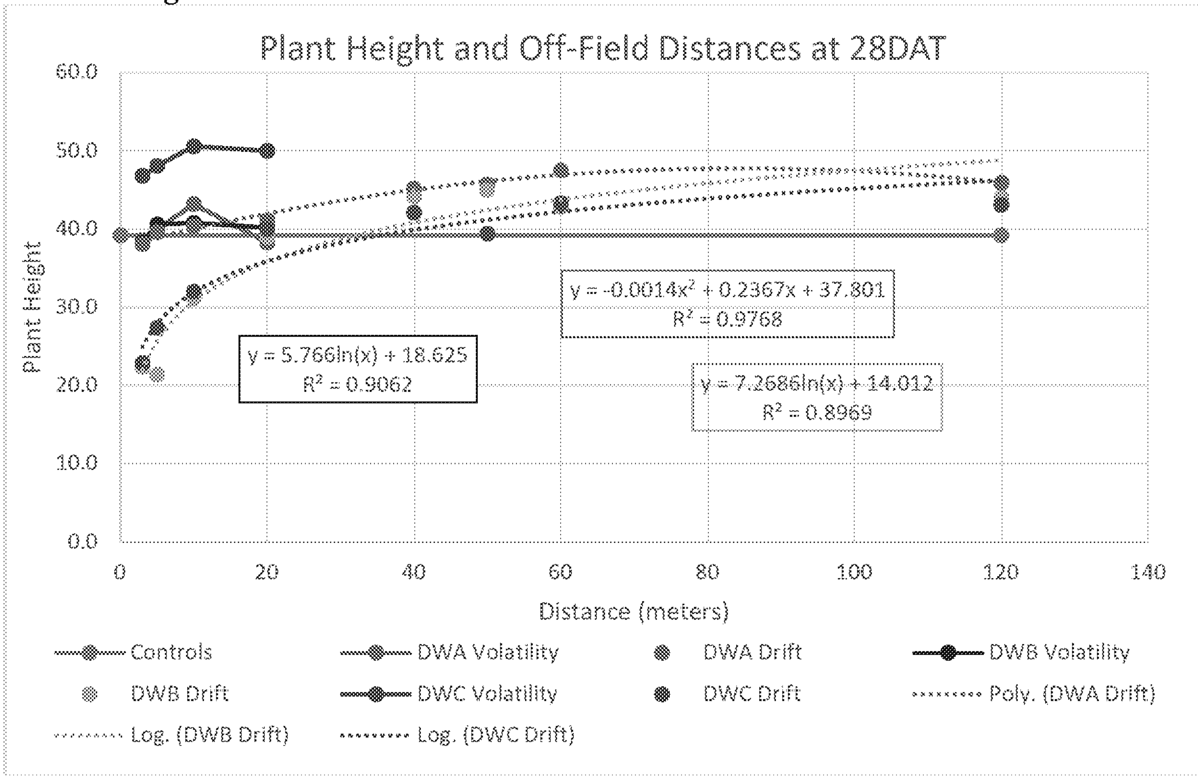
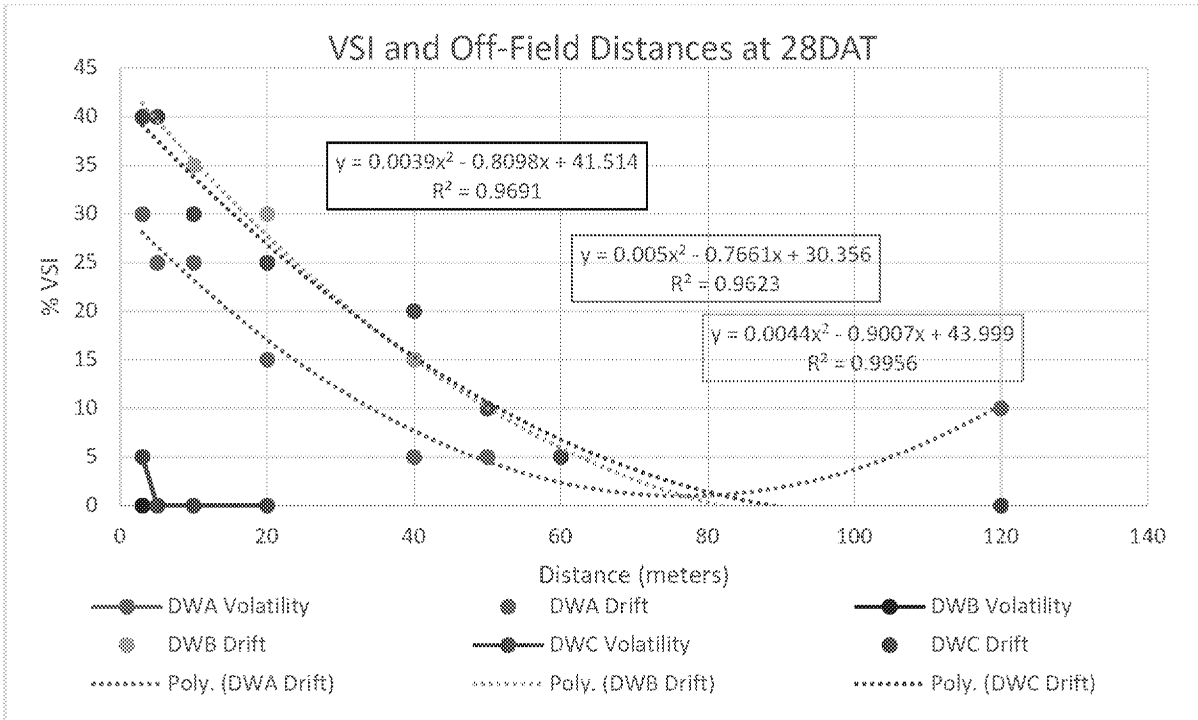


Figure 15: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Down Wind Transects".



III. Study Deficiencies and Reviewer's Comments

1. The registrant included the use of an approved buffering agent in the tank mix, potentially to mitigate volatility. While the addition of a neutral buffering agent is permitted on the label, its use was never discussed in the submitted protocol and may have reduced the volatility one would expect to observe in an application that did not include the agent.

2. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 542). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

3. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, slope estimates, pesticide and crop history, soil taxonomy, and study weather data (p. 3).

4. The first air monitoring period started after the conclusion of application.

5. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

6. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) for some sampling periods but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well.

7. Soil was characterized (Appendix B, p. 108, and Appendix B, Table 2, p. 123), but no taxonomic classification was provided. The custom soil resource report indicated that the area was predominantly Hoyleton silt loam (32.7% of area of interest) and Virden silty clay loam (33.9% of area of interest; Appendix B, pp. 185-210).

8. Soil characterization (texture, bulk density and organic matter content) were reported at only a single depth of 0-6 inches (Appendix B, Table 2, p. 123).

Study Deficiencies: Plant Effects

1. A heavy rain event (1.7 in.) occurred 5 days after application and subsequently impacted growth effects due to flooding and ponding in the test fields in upwind transect A (UWA). As a result, the UWA transect could not be evaluated at 3 and 5 meters, and the data for 10 meters was removed from the study author's statistical analysis. There was a clear drainage path through the upwind area where runoff flowed and washed out plants. The symptomology rating in the UWA transect at 10 m was anomalously high, likely due to physical damage and potential dicamba exposure from runoff. The variable impact of the flooding on plant growth may have confounded test results.

2. The study author calculated effects based on fit to piecewise non-linear curves, which included individual transects DWA, DWB, and DWC; the study author did not report if control plant height was incorporated in this modeling. The reviewer analyzed the entire height data set for each transect and compared data to plants in the control field.

3. The Stine PGL3590 variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

4. Following application for both the volatility and spray drift portions of the study, the study author notes that, "Plants were selected non-systematically with no attempt made to measure the same plant during subsequent sampling events" (Appendix G, p. 732).

   OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. The reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

5. The diagonal transects included one replicate of 10 plants per distance from the treatment field, and due to the lack of sufficient replicates/data, the Dunnett Multiple Comparison test was unable to determine significance of height effects and NOAEDs. The plants in the north diagonal transect (ND) and east diagonal transect (ED) are adjacent to the downwind transects and may be expected to show height effects.

6. Transects, except the downwind drift transect, totaled 10-20 plants for analysis per distance instead of 30 overall as recommended by OCSPP guidance.

7. Survival of plants in each test plot was not determined. OCSPP guidance recommends measuring effects on survival as part of the vegetative vigor test. Dry weight of plants in each test plot was also not determined. OCSPP guidance recommends measuring effects on plant biomass as part of the vegetative vigor test.

8. Soybean was the only species tested, OCSPP guidance recommends testing 4 monocots and 6 dicots.

9. The study author did not provide historical germination rates for the soybean varieties planted.

10. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported.

11. The physico-chemical properties of the test material were not reported.

IV. **References**

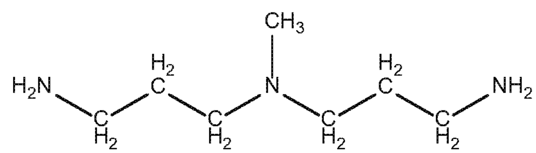
Gavlick, W. (2016). *Determination of a No Effect Crop Response as a Function of Dicamba Vapor Concentration in a Closed Dome System*. Monsanto Company. MSL0028204. MRID 50578901.

US EPA. (1998). *Spray Drift Test Guidelines, OPPTS 840.1200 Spray Drift Field Deposition*. United States Environmental Protection Agency, Prevention, Pesticides, and Toxic Substances. EPA 712-C-98-112.

US EPA. (2012). *Field Volatility Study Review Guide*. United States Environmental Protection Agency.

US EPA (2013). *Data Evaluation Report on the Toxicity of Clarity 4.0 SL (AI: Dicamba) to Terrestrial Vascular Plants: Vegetative Vigor*. United States Environmental Protection Agency, Washington D.C. MRID 47815102.

DER ATTACHMENT 1. Dicamba BAPMA and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba BAPMA (N,N-Bis-(3-aminopropyl)methylamine salt of dicamba; BAS 183 22 H)	**IUPAC:** N'-(3-aminopropyl)-N'-methylpropane-1,3-diamine **CAS No.:** 105-83-9 **Formula:** $C_7H_{19}N_3$ **MW:** 145.25 g/mol **SMILES:** NCCCN(C)CCCN	 	835.8100 Field volatility	51049004	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

   100094_51049004_DE
   R-FATE_835.8100_5-11

2. Validation spreadsheet for the Indirect Method

   100094_51049004_DE
   R-FATE_835.8100_5-11

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

   100094_51049004_DE
   R-FATE_835.8100_5-11

4. Validation spreadsheet for the Aerodynamic Method:

   100094_51049004_DE
   R-FATE_835.8100_5-11

5. Air modeling files

   100094_51049004 air modeling.zip

6. Validation spreadsheet for spray drift calculations

   100094_51049004_DE
   R-FATE_840.1200_8-2S

7. Terrestrial Plants: Vegetative Vigor.

   19-058-B%20Plant%
   20Effects%20Data.xls›

Attachment 3: Field Volatility Study Design and Plot Map

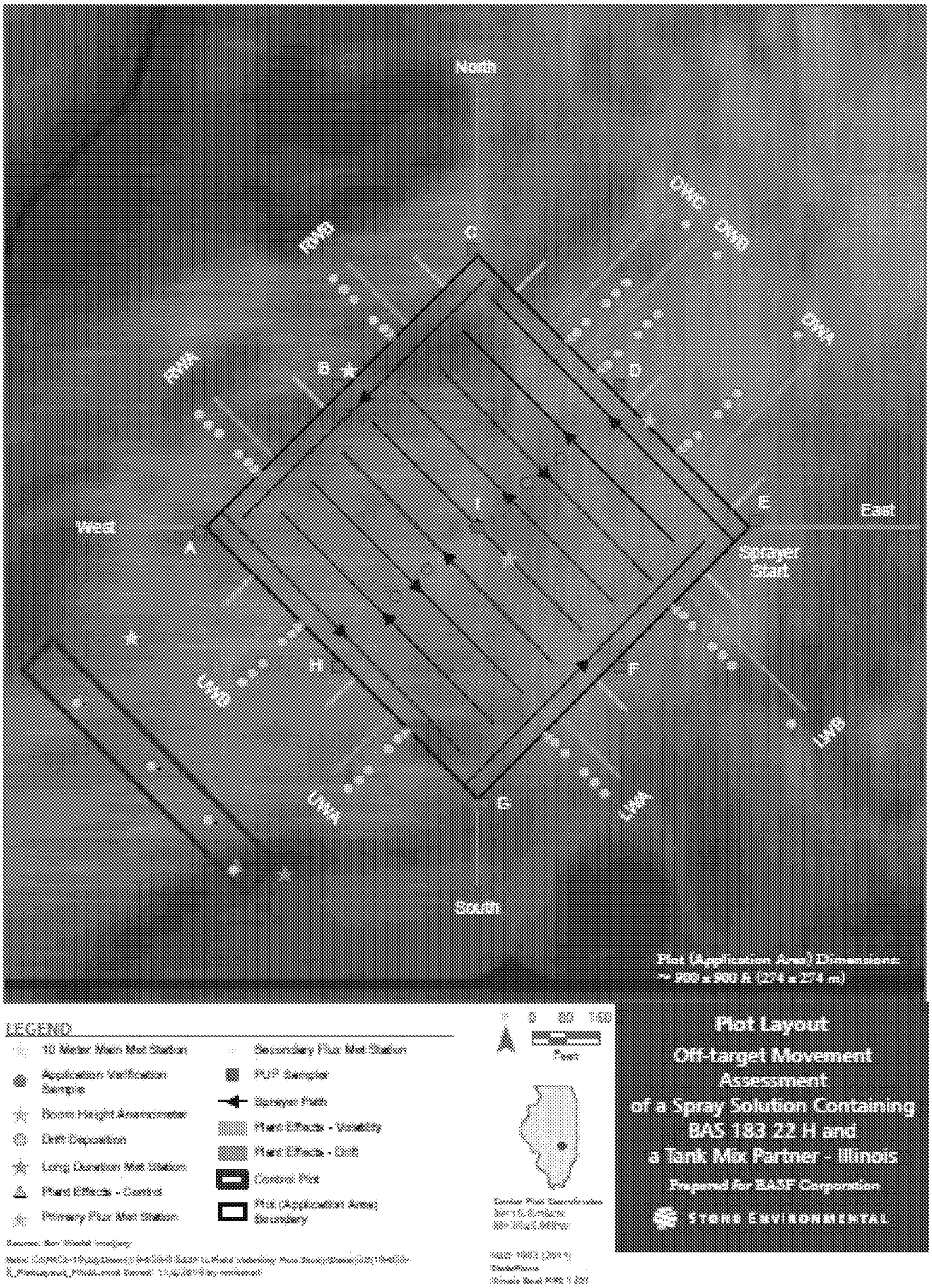


Figure obtained from Appendix B, Figure 2, p. 139 of the study report.